

Discussion of "A Review of Statistical Ideas Relevant to Intercropping Research",
by R. Mead and Janet Riley, Journal Royal Statistical Society, Series A, 144(4).

by

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ABSTRACT

There are many possibilities for analyzing data in addition to those discussed in the paper. This discussion extends the concepts and analyses presented in section 3. In particular, modeling of response variables for intercropping experiments at varying densities is discussed. The usefulness of modeling responses is emphasized.

Discussion of Paper by Mead and Riley

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The authors identify, at the very beginning of their paper, the many problems that arise in research on intercropping systems and emphasize the importance of the development of statistical techniques which could handle these problems. In Section 2, they discuss the various aspects of treatment design and experiment design that would best suit this type of research. Then, in Section 3, they consider two types of possible analyses, i.e., bivariate analyses and the use of the Land Equivalent Ratio, a particular index of the combined yields from an intercropping experiment, for the evaluation of intercropping systems.

There are, however, many other possibilities for the analysis of intercropping data, and I would like to extend Section 3 to include some further concepts and ideas for analysis. The use of other multivariate analyses on different types of observation vectors, and analyses on indices of combined yields other than the LER, which would evaluate intercropping systems from agronomic, economic, ecological and nutritional viewpoints, has already been discussed. This, I feel, is a very important area of analysis. I wish to further consider the possibility of fitting simple models to the observation variables, which would enable the intercropping systems to be evaluated in terms of the parameters of the model. The models would be developed to include such effects as competition and compensation among the different crops in the system.

A model whose parameters reflected the complex underlying biological structure of the intercropping system could be very useful in pinpointing types of crops and species of a particular crop, as well as crop combinations that benefitted from being grown as intercrops. Further, since the model

would break down the total yield from a crop into relevant components, a better concept of the system could be grasped than if the analysis were only performed on yields using the usual analysis of variance structure.

These abstract ideas may best be illustrated by the use of two examples of possible models, in different intercropping contexts:

- a) We consider an intercropping system where each of a number of genotypes of a single crop are to be evaluated on their performance when grown in a mixture with a single other genotype. We assume that for each genotype, the planting density at which yield is optimized in monoculture is known (and not necessarily equal for all genotypes). The performance of each genotype in mixtures is to be compared with its own performance in monoculture, and the performance of the other genotypes both in monocultures and mixtures. We consider a model for yield (or other observed variable) which could be specified in terms of a general mean for all genotypes (since these are genotypes of a single crop, the concept of an overall mean is acceptable), a particular genotype effect over and above the overall mean, a general mixing effect for each genotype, which would be an indicator of its overall ability to mix, and a specific mixing effect due to one particular genotype on another, which would indicate the ability of one particular genotype to mix with another particular genotype.

We consider a system where n genotypes are grown in monoculture at their optimum yielding densities and in all possible pairwise combinations, each at 50% of their monoculture densities. The model response equations for this system could be given by

$$Y_{iim} = \mu + \tau_i + \epsilon_{iim} \quad \forall \quad 1 \leq i \leq n \quad \text{for monocultures}$$

(where suffix m denotes monoculture)

and

$$Y_{i(j)b} = \frac{1}{2}(\mu + \tau_i + \delta_i) + Y_{i(j)} + \epsilon_{i(j)b} \quad \text{for mixtures}$$

$$Y_{j(i)b} = \frac{1}{2}(\mu + \tau_j + \delta_j) + Y_{j(i)} + \epsilon_{j(i)b} \quad \text{(where suffix b denotes biblends)}$$

$$\forall \quad 1 \leq i, j \leq n \quad i \neq j$$

Here

Y_{iim} is the yield of the i th genotype in monoculture;

$Y_{i(j)b}$ is the yield of the i th genotype when grown with the j th genotype in a mixture as specified above;

μ is an overall mean effect;

τ_i is the effect due to the i th genotype $\left(\sum_{i=1}^n \tau_i = 0 \right)$;

δ_i is the general mixing ability of the i th genotype $\left(\sum_{i=1}^n \delta_i \right.$ is not necessarily zero);

$Y_{i(j)}$ is the specific mixing ability of the i th genotype when grown with the j th genotype $\left(\sum_{\substack{j=1 \\ j \neq i}}^n Y_{i(j)} = 0 \quad \forall \quad 1 \leq i \leq n \right)$;

and

ϵ_{iim} , $\epsilon_{i(j)b}$, $\epsilon_{j(i)b}$ are random components of variation.

Parameter estimates could be obtained for each of the above with corresponding variances, and an assessment of the τ_i 's, the δ_i 's and the $Y_{i(j)}$'s would give a very clear picture of how each genotype was performing. For example, if $\delta_k - \bar{\delta} \gg 0$ for a particular k and $\frac{1}{2}(\delta_k - \bar{\delta}) + Y_{k(j)}$ was also positive for all $j \neq k$, this would indicate that the k th genotype did well as a mixer. $\bar{\delta}$ being positive would imply that the crop in general did well as an intercrop with different genotypes, while $\bar{\delta} < 0$ would imply that the crop probably performed better in monoculture.

Variations on this theme could be used to encompass different percentage density combinations of genotypes, but the main point is that the general idea of assessing competitive ability in terms of the δ 's and γ 's could be a very useful analysis.

b) Another example would suffice to emphasise the usefulness of these types of models. Here we consider intercropping systems involving pairs of different crops, at varying densities. In this case, we assume that a yield density relationship exists and its functional form is known for each crop.

Thus in monocultures, for each crop i ($1 \leq i \leq n$) we have for the yield Y_{iim} ,

$$Y_{iim} = f_i(d) + \epsilon_{iim} \text{ where } f_i \text{ is the functional form of the } i\text{th crop as a function of density } d ,$$

(e.g.: For Y_i increases linearly with density, $f_i(d) = \beta_{0i} + \beta_{1i}d$) . We consider the yield of the i th crop when grown with the j th crop at densities d_i , d_j , respectively, as given by

$$Y_{i(j)b} = f_i(d_i) + \gamma_{i(j)}(d_i, d_j) + \epsilon_{i(j)b} ,$$

where $\gamma_{i(j)}(d_i, d_j)$ is the effect due to the interaction of the two crops at those particular densities on crop i . To complete this model, an associated variance structure would be required and then generalized least squares theory would be used to obtain parameter estimates which would describe the performance of the cropping systems.

These are just two ideas of the many possible model structures in this context. We feel that this area should be further explored and applied to the evaluation of intercropping systems. Needless to say, the complexities

of obtaining suitable models and associated variance structures for different density and spatial arrangements does not make it easy, and the fundamental concepts underlying any model that is used need to be very carefully considered before any model is applied to the data.